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VISUAL SENSORY REINFORCEMENT IN  
THE GOLDFISH CARASSIUS AURATUS

by



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A THESIS

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UNIVERSITY OF ALBERTA  
FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "Visual Sensory Reinforcement in the Goldfish Carassius auratus.", submitted by Joseph David Clement in partial fulfilment of the requirements for the degree of Master of Science.



## ABSTRACT

Following Kish's suggestion that a broader comparative approach be taken in the study of sensory reinforcement (Kish, 1966), visual sensory reinforcement was studied in the fish Carassius auratus. Using a "fish version" of Butler's visual exploration apparatus (Butler, 1953), it was found that 1) Light onset contingent on pressing a target, increased the rate of responding and 2) varying the visual sensory consequences of the response quantitatively varied the response rate.

This was interpreted as being analogous to the findings made in similar studies using higher order vertebrates; and thus indicating the apparently basic nature of sensory reinforcement and, as Berlyne has suggested, the role that exploratory behavior may have in affecting the prospects of survival for an organism (Berlyne, 1960).



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Also I wish to acknowledge a man who, although not directly concerned with this thesis, has taught me the difference between collecting data and observing behavior; and that research can be enjoyable, not tedious. Thank you, Dr. J.V. Haralson.





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The fish who maneuvers through complex terrain, who identifies dangerous predators, and who remains alert for a female companion must experience the visual and emotional decisions familiar to his more elevated vertebrate cousins. In the world of fish we find the rudiments of selection, anticipation, exploration and intelligence. In search of a psychology applicable to human beings we should not stop with a visit to the monkey house at the zoo, but reserve some thoughtful hours in a good aquarium.

(Ingle, 1967, pg. 50)





## CHAPTER 1

### Introduction

#### A. Origin of Problem

Sensory reinforcement is a term used by some investigators to refer to a "primary reinforcement process resulting from the response-contingent presentation or removal of stimuli of moderate intensity (Kish, 1966, p. 110)." Typically, this process has most commonly been associated with what is referred to as exploratory behavior (Barnett, 1958; Montgomery, 1953; Harlow, 1953) or curiosity (Berlyne, 1950; Berlyne & Slater, 1957).

In 1925, Dashiell found that rats would traverse a checker-board maze even when they were not hungry or thirsty. This was probably the first systematic observation of what was later to be denoted by the general term "exploratory behavior."

Consequential research in this area waned however, until the early 1950's. The resurgence of interest at that time was due primarily to the development of classical drive theory (Hull, 1943) and the critics of this position. Of singular importance was the concept that the theoretical mechanism for reinforcement was that of drive stimulus or tension reduction (Dollard & Miller, 1950; Hull, 1952). This theoretical mechanism



came into empirical conflict with the findings on manipulatory behavior which indicated that organisms will participate in activities which increase their total stimulation (Harlow, 1950).

Exploratory behavior is a general expression and several diverse methodologies have been incorporated in the study of the various components. In his chapter in Honig, Kish considers these major techniques. The discussion which follows is based largely on the comments made by Kish (1966).<sup>1</sup>

#### Locomotor Exploration

This was one of the earliest techniques used and has continued to be one of the most popular. Essentially the organism is placed in a "novel" test situation (i.e. Y-mazes, runways, etc.) and its movements observed and noted.

Kish notes three major difficulties with this approach; (1) the stimuli which are seen as being reinforcing are extremely complex (including visual, tactual, olfactory, kinesthetic, and auditory stimulation occurring simultaneously), (2) "the precise functions of the stimulation are difficult to specify since the stimuli are often present prior to as well as consequent upon the activity of the organism," (p. 115); and (3) the dependent

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1. For recent reviews of the literature see Fowler, 1965; Cofer & Appley, 1967, Chp. 6; and Kish, 1966.





variable in these studies (overt locomotor activity) could be a reflection of many possible variables acting on the organism, rather than a simple reflection of exploratory behavior.

### Curiosity

Berlyne, in 1950, used as his dependent variable the number of contacts an organism made with various stimuli. This procedure is not confounded with those variables which interacted with simple overt locomotor activity since these variables would be held constant over the different stimuli.

However, this method does not effectively reduce the complexity of the stimuli; and, most probably, several sense modalities are utilized in a single contact with a single stimulus.

This technique has been used in a number of studies and has been interpreted as an operational index of curiosity.

### Light Onset Reinforcement

A number of investigations have shown that rats will learn to press a lever if it is followed by an increase in illumination (e.g. Girdner, 1953; Kish, 1955; Kling et al., 1956; Hurwitz et al., 1958). Other studies have found just the reverse; rats will learn to bar press if the response is followed by a termination of illumination (Roberts et al., 1958). In fact Barry and Symmes (1963) has found that bar pressing was reinforced regardless of whether it turned the light on or off.



Investigators have sought to resolve this discrepancy and have found and isolated some relevant variables. Lockard (1962) has shown that bright light intensities tend to be more aversive to animals which had previously been kept in the dark when compared to animals which had previously been kept in the light; thus previous experience is important in determining the effect of changes in illumination. Levin and Forgas (1959) have demonstrated that age is another crucial variable.

Kish (1966) ignores this research and suggests that in the 10 per cent of his studies where he failed to find light onset reinforcement, the failure was due to methodological difficulties. Most probably Kish is correct to some degree; but attention must be made to organismic and situational variables that have been shown to have an effect.

### Visual Reinforcement

In the 1950's Butler developed a technique in which a subject, who had been placed in a light proof cage, could, by means of performing some task, open an aperture and thus provide himself with visual stimulation (Butler, 1953). Utilizing this method, it was found that the characteristics of the stimulation had a quantitative effect on the magnitude of reinforcement (Butler, 1954).

Because of the control this procedure affords the experimenter Butler's method provides an optimal situation in which to study





the properties of sensory reinforcement. It is optimal in the sense that, like the light onset studies, the response is very specific; and it allows for the presentation of a wide range of response contingent visual stimulation as in the curiosity studies.

Along with the empirical research have evolved several theoretical interpretations. Fowler (1965) has differentiated four major theoretical positions; (1) exploratory drive, (2) curiosity, (3) boredom, and (4) optimal stimulation.

#### Exploratory Drive

"The hypothesis of exploratory drive, developed by the writer...states (a) that a novel stimulus situation evokes in an organism an exploratory drive which motivates exploratory behavior, and (b) that strength of exploratory drive as measured by the amount of exploratory behavior decreases with time of continuous exposure to a given stimulus situation and recovers during a period of nonexposure (Montgomery, 1953, p. 46)."

Thus Montgomery describes his concept of exploratory drive. Similarly Harlow has on various occasions (e.g. 1953) argued for the existence of a visual exploratory drive. These investigators, primarily Harlow, felt that "homeostatic" drives or "internal" drives, that had been postulated by classical drive theory, could not account for all motivational processes; that in fact some behaviors of man and lower organisms were elicited



by certain types of external stimulation.

Critics of this position noted, however, (1) that attributing a behavior to the behavior's drive was circular and provided little insight into the nature of the behavior; and (2) the stimuli which elicit the drive also function to reduce it (Brown, 1953; Estes, 1958; Bolles, 1958).

### Curiosity Drive

Almost synonymous with the exploratory drive position was that espoused by Berlyne (1950). Basically, novel stimuli were seen as affecting the receptors of the organism which resulted in a drive-stimulus-producing response (curiosity). As the organism continued to be affected by these stimuli the level of curiosity decreased.

The same criticisms that were made against the exploratory drive concept can also be made here.

### Boredom

"...we suggest that drives produced by homogeneous or monotonous stimulation, enforced inaction, etc., may be reduced by sensory variety, freedom of action, etc., and that such drive reduction is the reinforcement involved in learning for 'exploratory', 'manipulatory', and 'exercise' rewards (Myers & Miller, 1954, p. 434)."

By such an interpretation, Myers and Miller reconcile





exploratory behavior with classical drive theory. There has been experimental evidence to support this conception. Butler (1957) varied the amount of visual deprivation in monkeys prior to studying visual exploration. He found that those animals which had been deprived the longest demonstrated the most visual exploratory behavior. More recent studies have supported Butler's finding (Isaac, 1962; Fox, 1962). However Kish (1966) has reported that some unpublished studies have not reported similar effects, and in some cases have found just the opposite. Therefore the boredom position has not been totally supported by the empirical evidence.

#### Optimal Stimulation-Arousal

The exploratory and curiosity drive positions could account for the studies in which the organism proceeds to emit exploratory behavior. According to these positions the animal would explore because the novel situation (or novel stimuli) created a drive state and exploration would serve to reduce this drive.

However, these positions cannot account for the situation in which the subject performs tasks in order to expose himself to stimulation. It is this latter case that the boredom position chiefly applies itself.

In 1965, Leuba developed the concept of optimal stimulation. The essential principle is stated by the following: "the organism tends to acquire those reactions which, when overall stimulation



is low, are accompanied by increasing stimulation; and when over-  
all stimulation is high, those which are accompanied by decreasing  
stimulation (p. 28f)." This position, then, could account for both types of behavior mentioned above.

Combining Leuba's work with Hebb's notion of an arousal system (1955), Fisk and Maddi (1961) and Berlyne (1963) developed similar theories based on a concept of optimal arousal. These theories are homeostatic in nature. Figure 1 shows a schematic representation of these positions.

According to Fisk and Maddi, for any particular task there exists a physiological optimal level of arousal (OL) for effective performance (line A in fig. 1). Deviation from OL is seen as undesirable, and the organism's behavior will be directed so as to return to the OL. Introduction into a novel situation, or of a novel stimulus, results in a rise in the level of arousal (line B). Exploration of these novel elements reduces the arousal to the OL (line C). If the organism is placed in a homogeneous or monotonous situation, over time there will be a decrease in arousal from the OL (line D). Since this is not desired, the subject will seek stimulation thus raising his level of arousal back to the OL (line E).

Berlyne differs from Fisk and Maddi in that he conceptualizes monotonous situations, as well as novel situations, as being arousing (line F), and that all forms of exploratory behavior are directed towards the reduction of this aroused state (line G).





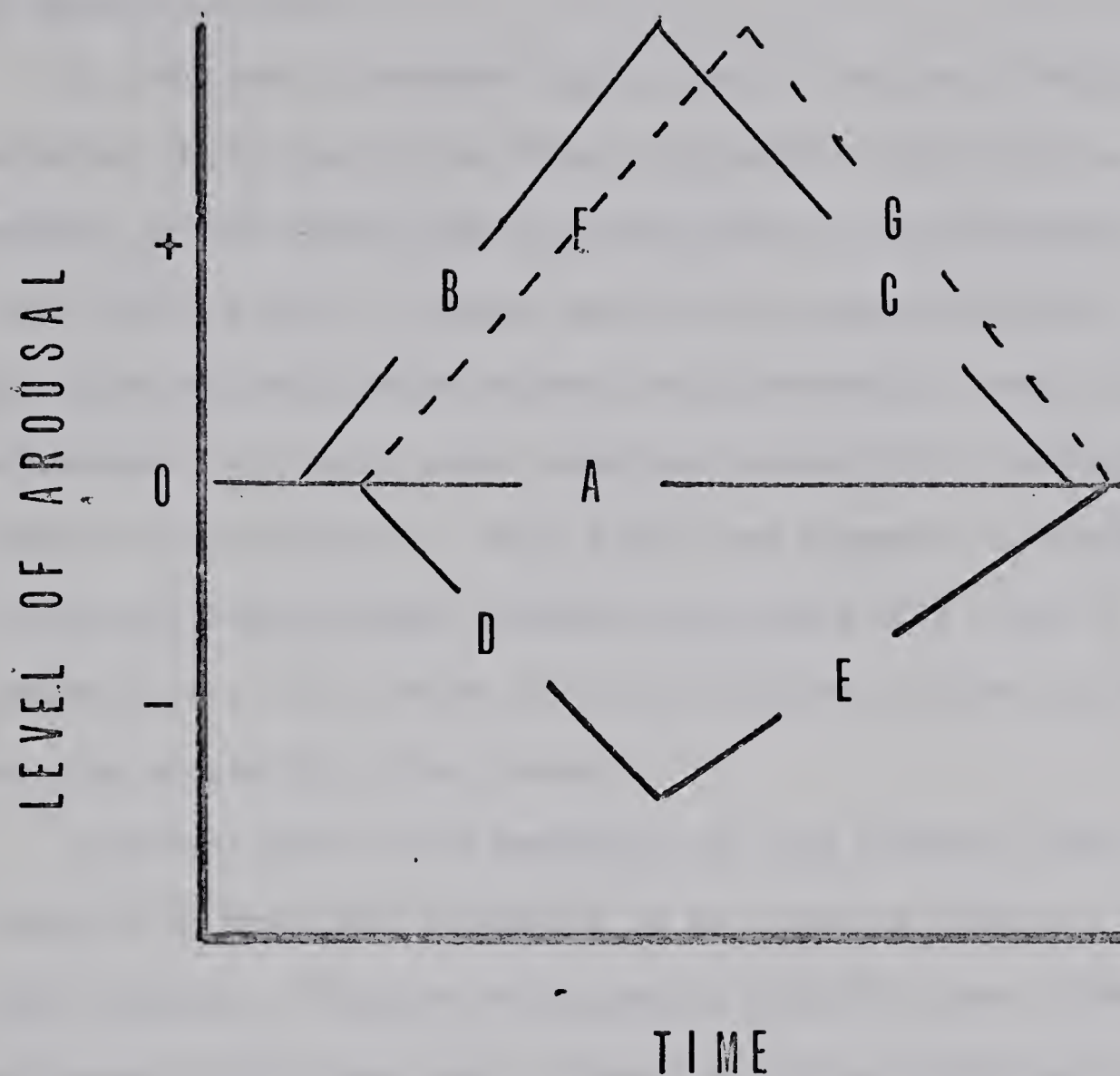


Figure 1 Model of optimal arousal positions

- A. Optimal arousal level (OL)
- B. Rise in level of arousal (LA) due to presentation of novel stimulus (Fish & Maddi, 1961)
- C. Return to OL due to exploration
- D. Decrease in LA due to boredom
- E. Return to OL due to seeking of stimulation
- F. Rise in LA due either to presentation of novel stimulus or to boredom (Berlyne, 1963)
- G. Reduction in LA due to exploration and/or seeking of stimulation



## B. Specific Problem

In reference to research being done in the area of exploratory behavior, Harlow has stated "that a systematic investigation anywhere in the phyletic scale should prove of methodological value (1953, p. 29)." However most of the research done in this area has demonstrated sensory reinforcement in human adults, chimpanzees, and rats; these organisms representing relatively higher order vertebrates. Kish (1966) has suggested that while the sensory reinforcement principle may have a wide range of applicability, more species need to be studied in order to determine the generality of the concept.

A further test of the generality of this behavior would therefore be provided by studying in an analogous fashion a lower order organism. Haralson has suggested that fish have a lower exploratory drive than rats, although he did not empirically determine this (Haralson, 1964). Fish would therefore be an interesting organism with which to comparatively study sensory reinforcement.

Specifically, it is hypothesized that if sensory reinforcement is present in fish, then there will be an increase in the rate of a response (i.e. pressing a target) if that response is followed by moderate sensory stimulation (i.e. onset of a light). Further, it is hypothesized that if the general findings concerned with stimulus complexity (Welker, 1956a; 1956b; 1956c; Barnes & Baron, 1961; Mason & Harlow, 1959; Miles, 1962) apply



to fish then there will be an increase in the rate of the response as the consequences of that response increase in complexity<sup>1</sup>; the properties of complexity being defined (1)"...complexity increases with the number of distinguishable elements; (2)...complexity increases with the dissimilarity between elements; and (3)...complexity varies inversely with the degree to which several elements are responded to as a unit." (Berlyne, 1960. pps. 38-39)

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<sup>1</sup>•Generally these findings support the notion that increasing complexity adds to the reinforcing magnitude of sensory stimulation.





## CHAPTER 2

### Method

#### Subjects:

Twenty common goldfish (Carassius auratus) aged between 4 and 8 months at the start of the study and purchased from a commercial source were used in the study proper. Nine of these cyprinids were also used in subordinate studies discussed in Appendix A and Appendix B.

Individuals which served as subjects were preselected in the following fashion: a single fish was placed in the test apparatus for 1 hour. If during that interval the fish emitted at least 1 response, that fish was used as a subject (during this period a bar press was not reinforced). This was done simply as a facilitatory measure thereby eliminating "shaping" the fish.

#### Apparatus:

Research was conducted in two adjacent rooms. Room 1 contained the experimental tanks and room 2 contained the electronic apparatus.

The experimental tank was 20" X 10" X 12" and was divided into two compartments; one being 14" X 10" X 12" (the reinforcement



compartment), the other 6" X 10" X 12" (the experimental compartment). The compartments were separated by two dividers.

One of the dividers was the aperture wall and is shown in Figure 2. It was 10" X 12", made of white  $\frac{1}{4}$ " Plexiglas. A 3" X 6" window was cut 2" from the bottom and 2" from the sides. A door ( $3\frac{1}{2}$ " X  $6\frac{1}{2}$ " ) was placed over the window by means of two guides. The door was connected by means of a wire to an inverted Lehigh Valley Electronics dipper Model number 1351, such that when the solenoid of the dipper was activated, the door would be raised three inches.

The second divider was either made of clear Plexiglas or translucent Plexiglas, depending on the particular condition under which the subject was being run. The reinforcement compartment was illuminated by a 12-volt light (GE model 1881) situated 2" above the water level. This light was on continuously during all trials except the control condition.

A  $\frac{3}{4}$ " circular disc made of black Plexiglas with a  $\frac{1}{2}$ " X  $\frac{1}{4}$ " piece of white Plexiglas placed horizontally on the disc constituted the target. The target was placed 1" from the bottom and 1" from the aperture wall by means of a 15" brass rod. The free end of the brass rod was bent and placed over a pivot point; from there the end of the rod was placed in a piece of Plexiglas. This Plexiglas was then balanced over a microswitch. The microswitch could be raised or lowered thereby allowing for the adjustment of sensitivity. The resistance of the target was approxi-



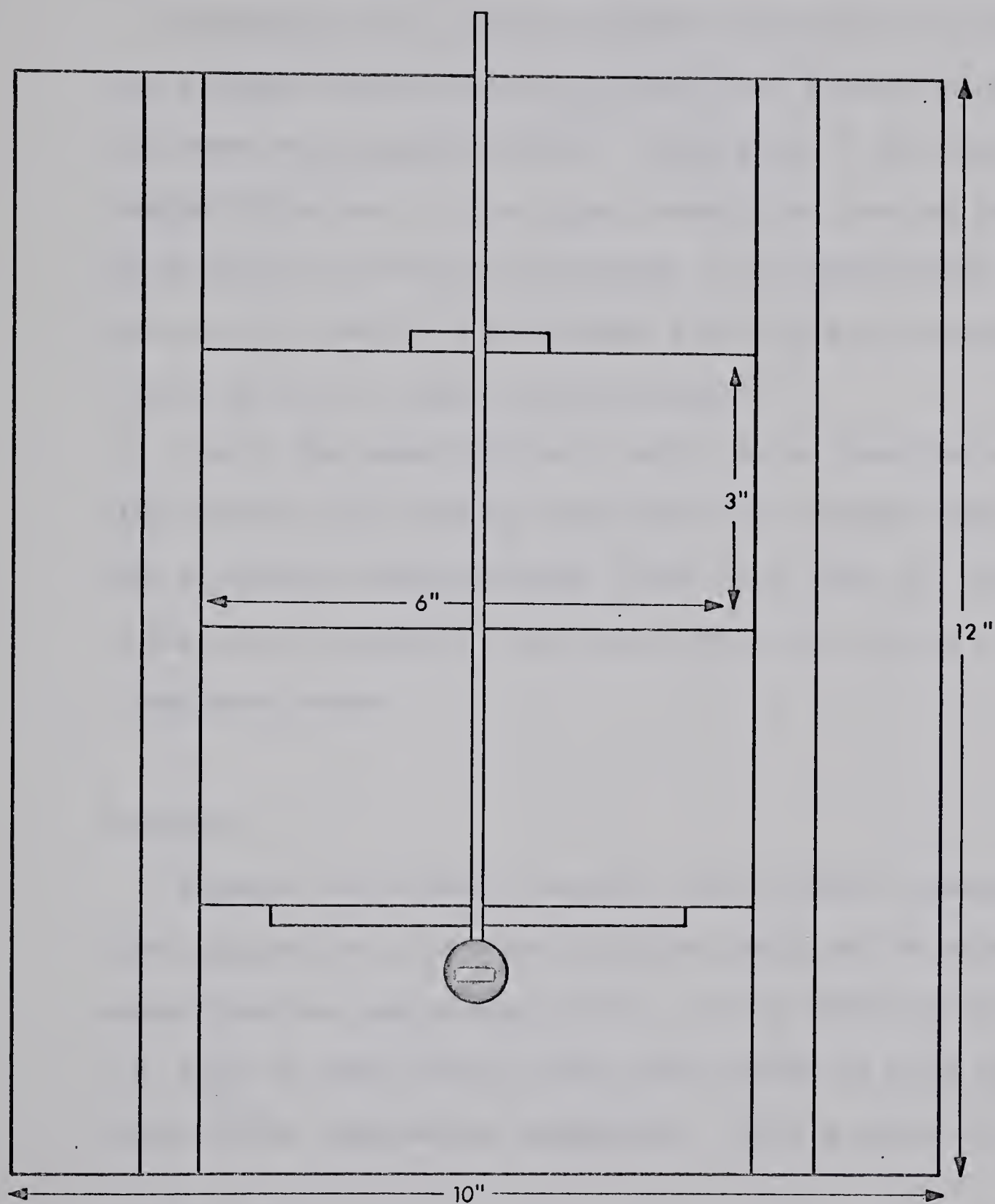


FIG 2 TARGET & APERTURE WALL







mately 2 gm.<sup>1</sup> Figure 3 shows the target assembly while Figure 4 shows the overall view of the experimental tank.

Depression of the target resulted in an impulse being fed into a Grason-Stadler Electronic Timer (model E5350A) mounted on a power rack located in room 2. Activation of this timer powered the solenoid of the dipper, opening the door and thus exposing the reinforcement compartment to the experimental compartment for a period of 10 seconds; also this timer registered a count on one of a bank of four counters.

Also on the power rack was a Lehigh Valley Electronics timer (model 1419) which was connected with a stepper relay. This allowed for hourly response counts to be taken and recorded on the bank of counters; 1 hour per counter for a period of 4 continuous hours.

#### Procedure:

Subjects were housed in separate tanks between treatments. Water temperature in both the individual tanks and the experimental tanks was approximately 21° C. On the first day of running a S would be taken from his some tank by means of a net and placed in the experimental compartment. After a period of 15

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<sup>1</sup>Two apparatuses were used in the actual running. To compensate for any discrepancies in the manipulanda, the targets were interchanged between the experimental tanks and thus balanced for treatments. The mean difference between the two manipulanda was 16.21 responses.



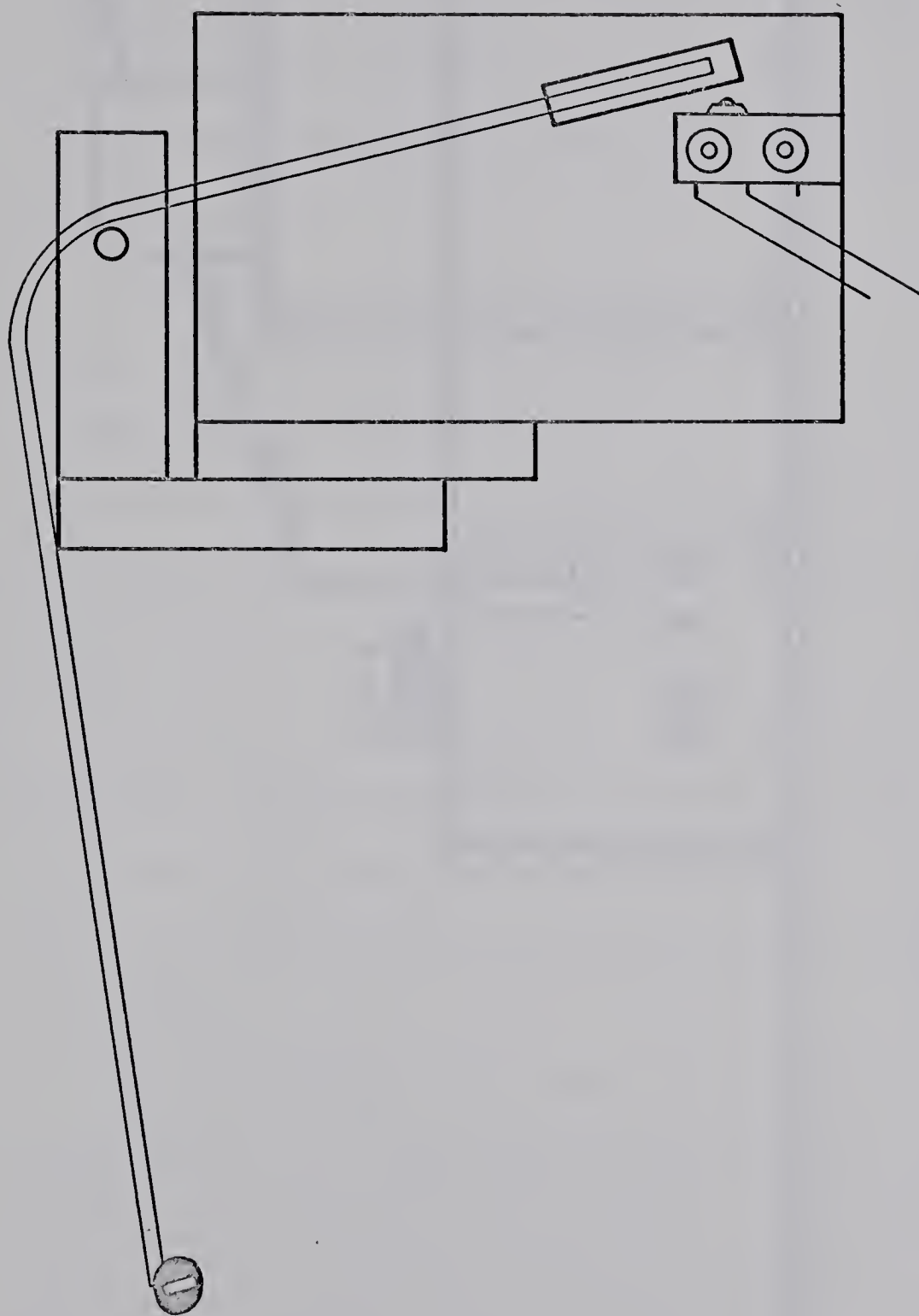


FIG 3 TARGET ASSEMBLY



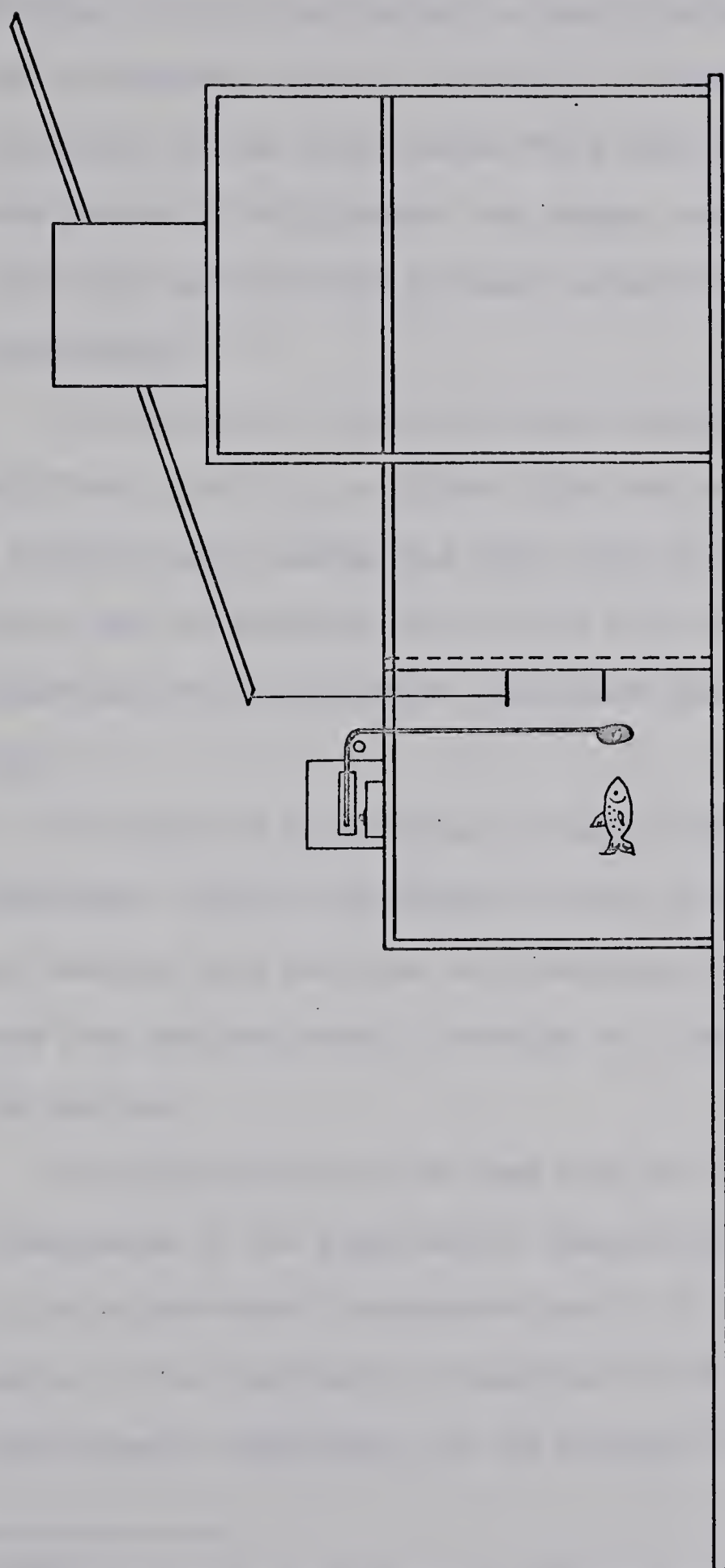


FIG 4 OVERVIEW of APPARATUS





minutes, to allow the subject to adapt (during this adaptation period responses were not recorded), the apparatus was put into operation; and the trial lasted for a four hour period. During this period if the S pressed the target, the door over the window would open and allow the S visual contact with the reinforcement compartment.

The contents of the reinforcement compartment were either: a diffuse light ( $E_1$ ), a diffuse light and two goldfish ( $E_2$ ), a diffuse light, plants, and rocks ( $E_3$ ), a diffuse light, plants, rocks, and two goldfish ( $E_4$ ), or the bar press would raise the window but the reinforcement compartment would not be illuminated ( $C_0$ ).

The order of presentation of these conditions was randomly determined. Each S was exposed to each of the conditions, one per session, with sessions being separated by 72 hours.<sup>1</sup> Ss were food satiated prior to running and food was available during the session.

The illumination of the home tank was 15 ft. candles; the illumination of the experimental compartment with the light off in the reinforcement compartment was 14 ft. candles; the illumination of the experimental compartment with the light on in the reinforcement compartment but the aperture door closed was

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<sup>1</sup>. From an earlier pilot study, 72 hours was found to be the optimal time for recovery between sessions. Summary of this pilot study is to be found in Appendix C.



32 ft. candles; and the illumination of the experimental compartment with the light on in the reinforcement compartment with the aperture door open was 50 ft. candles (as measured by Weston Illumination Meter Model 756).

Responses were counted over the session, with hourly totals also being recorded.

#### Design:

The data was analyzed by a  $2 \times 5 \times 4$  factorial design with subjects nested under time of running. This design allows for the extraction of variance due to time the S was run (morning or afternoon), the treatment effect ( $C_0$ ,  $E_1$ ,  $E_2$ ,  $E_3$ ,  $E_4$ ), the temporal effect (hour 1, hour 2, hour 3, hour 4) and the interactions of these main effects.



## CHAPTER 3

### Results

Figure 5 shows average responses over days. It can be seen from Table 1 that the emitted responses were not significantly affected by the particular day of running (Appendix D contains total responses emitted per day).

Half of the subjects were run in the morning (AM) and half in the afternoon (PM). The effect of this variable is found in the major analysis (Table 2). The results indicate that this potential cyclic activity had no differential effect.

Table 2 also shows that the treatments ( $C_0$ ,  $E_1$ ,  $E_2$ ,  $E_3$ , and  $E_4$ ), hour of trial ( $H_1$ ,  $H_2$ ,  $H_3$ , and  $H_4$ ), and the interaction of treatment with hours were all significant. A Duncan's multiple range test was used to determine which means differed significantly for the treatments (Table 3) and for hours (Table 4).

The range test for treatments revealed that each condition differed significantly from every other condition and Figure 6 reveals that the relationship between the treatments is monotonic. The range test on the hours shows that the only comparison which was not significant was between the first and fourth hour. The interaction of treatments with hours is graphically depicted in Figure 7. This interaction is interpreted largely as a function of the temporal characteristics of the responding, which is







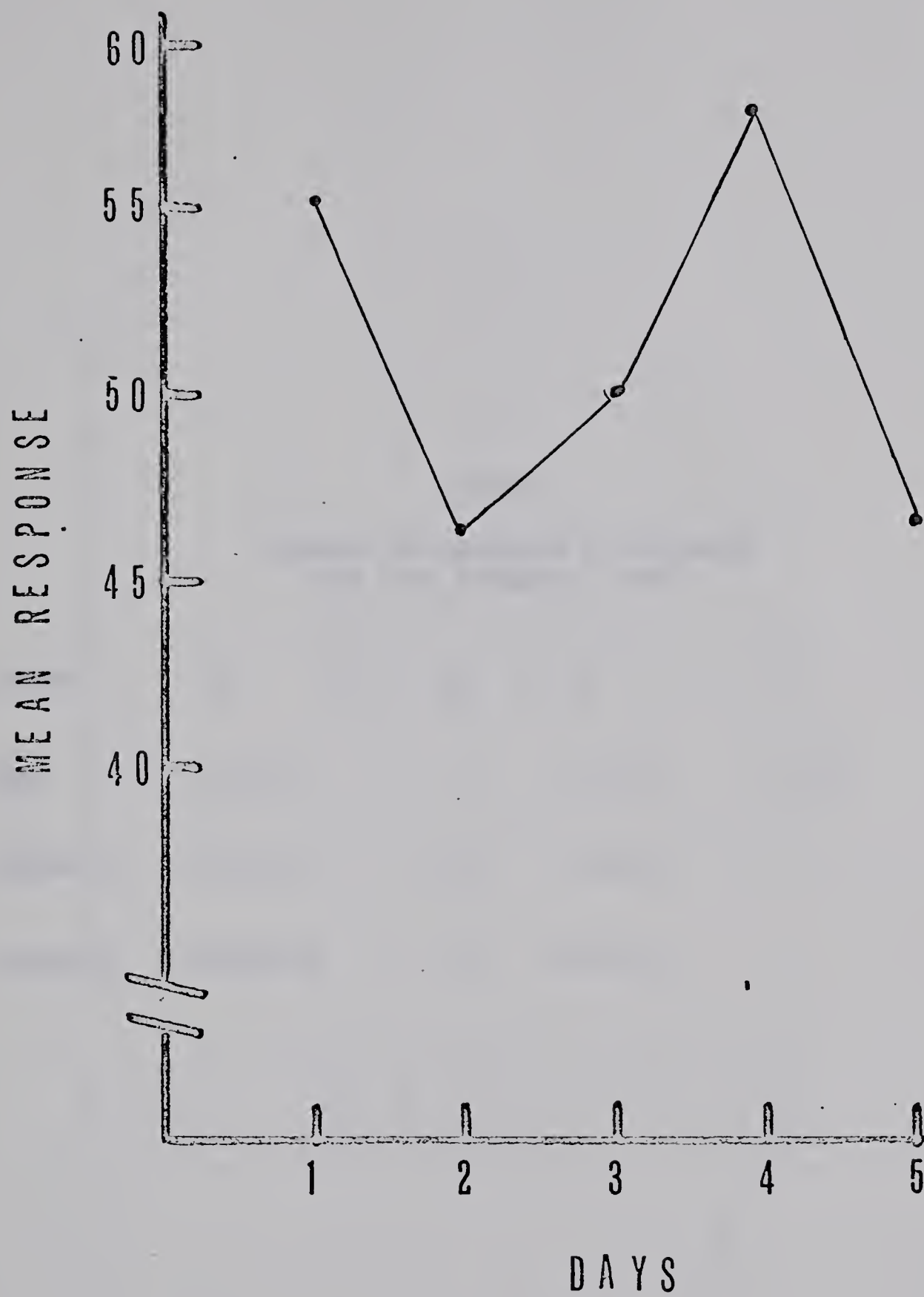


Figure 5 Average responses, summed over treatments, per day



TABLE 1

SUMMARY OF ANALYSIS OF VARIANCE  
FOR DAYS (EDWARDS, 1964)

Source	SS	df	MS	F
Days	1164.34	4	291.08	< 1.00
Subjects	10316.84	19	542.99	
Residual	110496.86	76	1453.91	



TABLE 2  
SUMMARY OF ANALYSIS OF VARIANCE FOR MAJOR VARIABLES (EDWARDS, 1964)

Source	SS	df	MS	F
Time(AM-PM)	.36	1	.36	< 1.00
Error (A)	2686.73	18	149.26	
Treatment	25830.37	4	6457.59	133.28 (p < .01)
Hours	12074.19	3	4024.73	83.07 (p < .01)
Treatment x Hours	6336.03	12	528.00	10.90 (p < .01)
Time x Treatment	48.91	4	12.23	< 1.00
Time x Hours	38.00	3	12.67	< 1.00
Time x Treatment x Hours	277.93	12	23.16	< 1.00
Error (B)	16571.07	342	48.45	





TABLE 3

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE  
TEST FOR TREATMENTS (EDWARD'S, 1964)

	C <sub>0</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>
C <sub>0</sub>	0	14.90**	26.55**	62.65**	87.50**
E <sub>1</sub>		0	11.65**	47.75**	72.60**
E <sub>2</sub>			0	36.10**	60.95**
E <sub>3</sub>				0	24.85**
E <sub>4</sub>					0

\*\*p .01



TABLE 4

SUMMARY OF DUNCAN'S NEW MULTIPLE RANGE  
TEST FOR HOURS (EDWARDS, 1964)

	H <sub>1</sub>	H <sub>4</sub>	H <sub>3</sub>	H <sub>2</sub>
H <sub>1</sub>	0	.48	8.30**	13.08**
H <sub>4</sub>		0	7.82**	12.60**
H <sub>3</sub>			0	4.78**
H <sub>2</sub>				0

\*\*p < .01



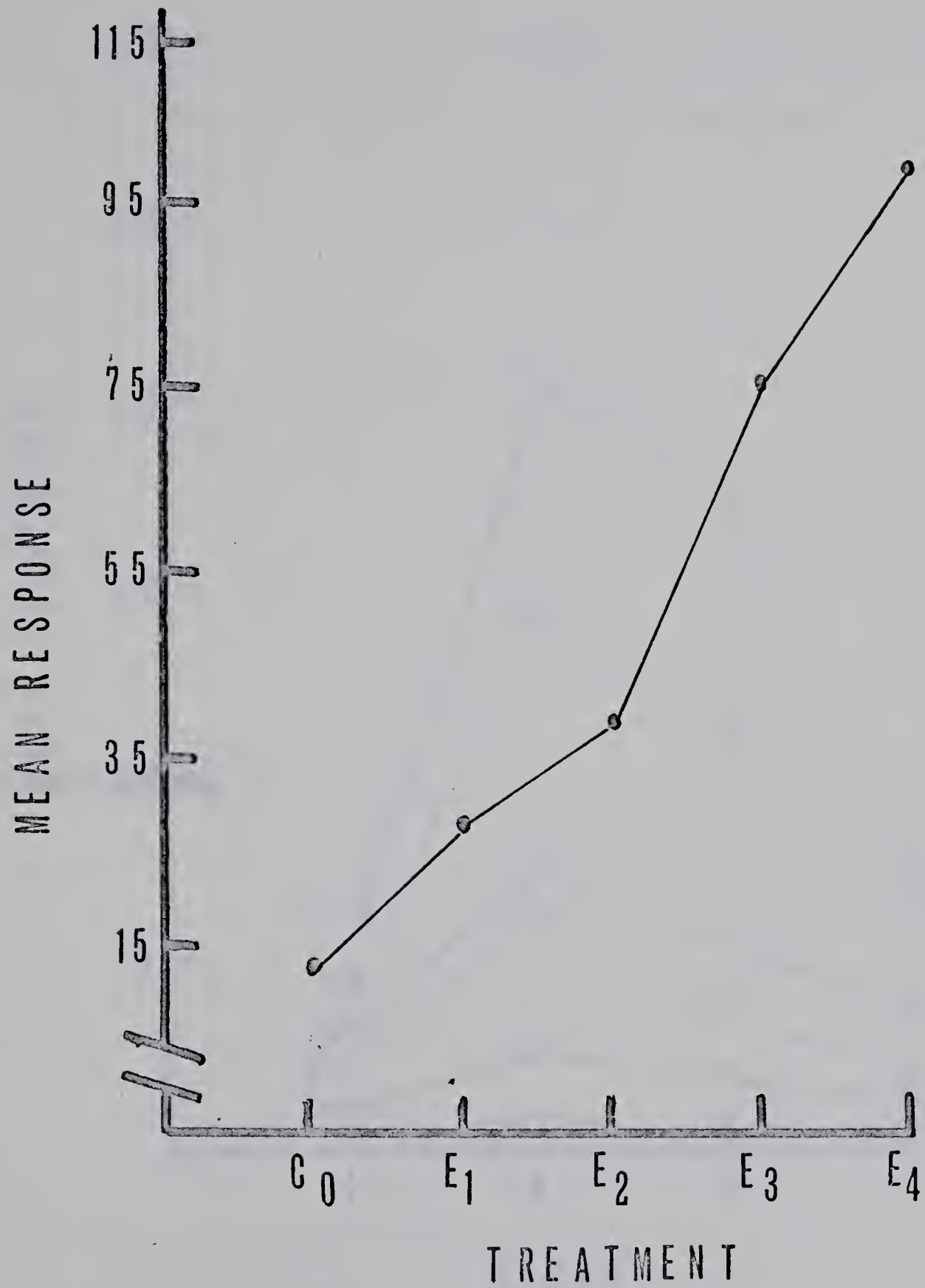


Figure 6 Average responses made per treatment





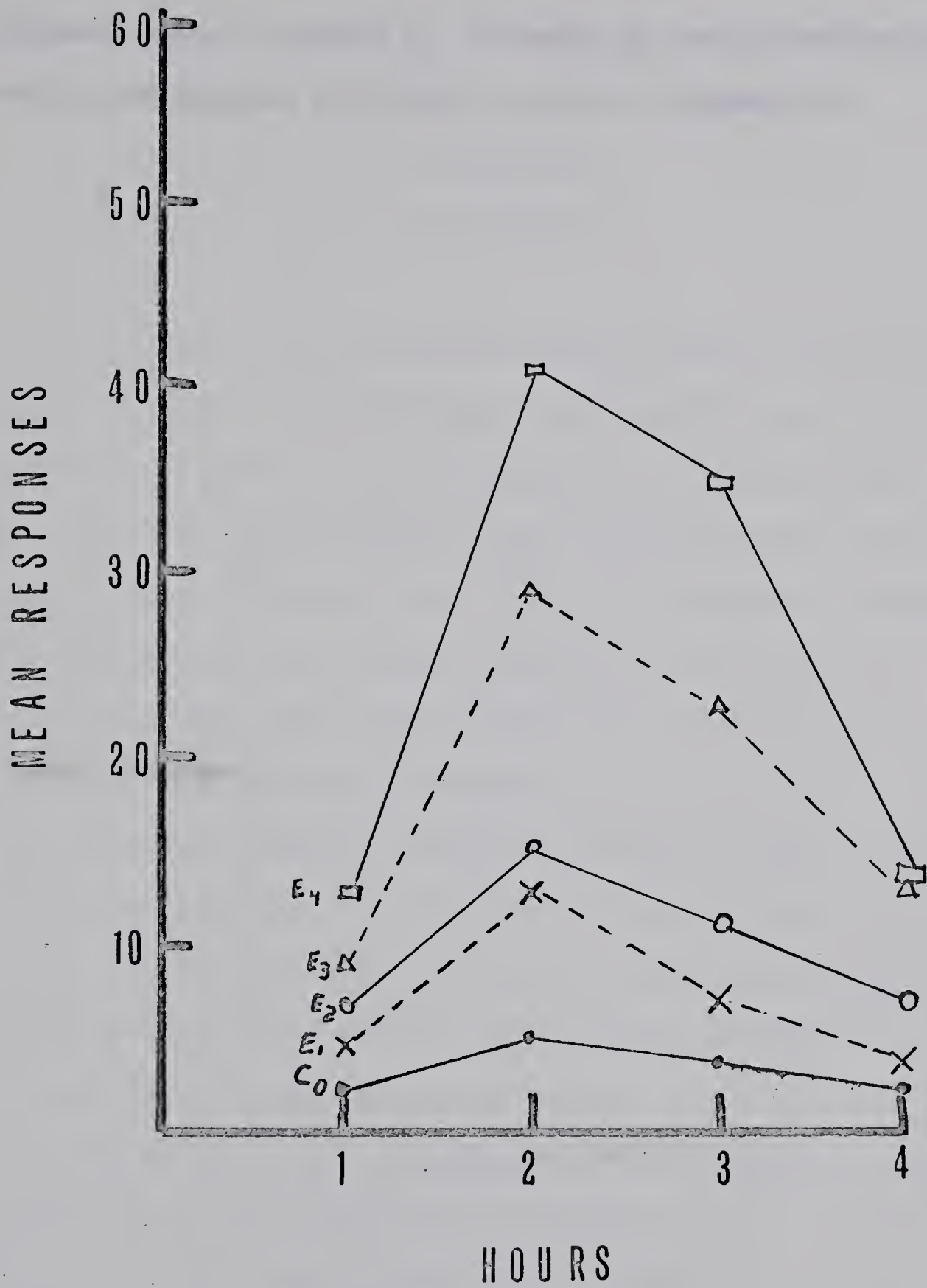


Figure 7 Temporal distribution of responses for each treatment (C<sub>0</sub>, E<sub>1</sub>, E<sub>2</sub>, E<sub>3</sub>, E<sub>4</sub>)



discussed later in Chapter 4. A summary of the raw data matrix used in the analysis for Table 2 is given in Appendix E.



## CHAPTER 4

## Discussion

There are a number of possible interpretations of the results. Typically in sensory reinforcement studies the stimuli are motivationally neutral. It could be argued in the present study that conditions  $E_2$ ,  $E_3$ , and  $E_4$  were not motivationally neutral, and that essentially the results support the findings of Thompson's work on the reinforcing characteristics of innate releasers (Thompson, 1963). This would follow if one assumes that the presentation of  $E_2$ ,  $E_3$ , or  $E_4$  served as a releaser.

Using this "releaser" interpretation as the mode of analysis, it would be quite difficult to determine the quantitative differences which were found in the present study; for example, why should the presence of rocks and plants be a more effective stimulus than the presence of other fish?

A derivation from the "releaser" position would be in considering  $E_4$  as representing the most natural situation with  $E_3$ ,  $E_2$ ,  $E_1$ , and  $C_0$  as being progressively less natural. If this position is used then it could be developed that the most natural situation ( $E_4$ ) represented the least novel condition while the least natural condition ( $C_0$ ) represented the most novel. If interpreted this way, the results are similar to those reported





in Sub-study I (Appendix A) in which a novel stimulus was found to have a decremental effect on the total emitted responses.

If one assumes that the presentation of novel stimuli is emotionally arousing, then following the hypothesis of Haralson and Clement (1968) the decremental effect of novelty can be interpreted. Essentially Haralson et al. has found evidence that when fish are in an arousing situation there is a breakdown in effective behavior; in the present study a breakdown in target pressing. This could be extended such that the more novel the stimulus, the more emotionally arousing the stimulus and hence the more disruptive the effect on appropriate behavior.

One major difficulty with this position lies in the assumption that light onset ( $E_1$ ) is more "natural" than the control condition ( $C_0$ ); and is, less novel than  $C_0$ . The rationale behind this assumption is questionable - on what basis can it be concluded that light onset is qualitatively or quantitatively different from  $C_0$  in terms of its natural or novel characteristics?

A third alternative explanation of the results depends on the ranking of experimental conditions in terms of complexity. As previously mentioned, Berlyne has identified the properties of complexity in the following way (1)"...complexity increases with the number of distinguishable elements; (2)...complexity increases with the dissimilarity between elements; and (3) complexity varies inversely with the degree to which several elements are responded to as a unit" (Berlyne, 1960, Pp. 38-39).



On the basis of the first 2 characteristics of complexity, the treatments could be ranked in terms of increasing complexity as follows: (1) control condition ( $C_0$ ), (2) light on-set ( $E_1$ ), (3) fish in the reinforcement compartment ( $E_2$ ), (4) rocks and plants ( $E_3$ ), and (5) rocks, plants, and fish ( $E_4$ ). When ranked this way the present findings are congruent with the conclusions of Barnes and Baron (1961); that there is a positive monotonic relationship between response rate and complexity. However, the third property of complexity referred to by Berlyne is difficult to operationalize and the above ranking of conditions may be misleading because of this component of complexity.

Because of the variety of possible interpretations the results concerning  $E_2$ ,  $E_3$ , and  $E_4$  cannot be taken as a clear demonstration of the effect of complexity on sensory reinforcement. However, condition  $E_1$  (light onset) is a definitive demonstration of visual sensory reinforcement. It is analogous to those studies reported in Chapter 1 under light on-set reinforcement; and the findings are similar to those of Girdner, 1953; Kish, 1955; and Hurwitz et al. (1958). In the present study  $E_1$  was unidimensional in that only one intensity and only light onset were investigated. It may be of interest in future work to vary the intensity of the light and also study light off-set.

The data suggests a significant temporal effect of responses over time. A look at this aspect of the study may prove of some interest. From Figure 7 it can be seen that in Hour 1 compar-





atively few responses were made, and the differences between treatments were small. This first hour could be interpreted as an adaptive period in which, initially, fear is elicited from being taken from the home tank and placed into a new environment. This fear could conflict with exploratory tendencies (Montgomery, 1955). Over time, as the S became more familiar with the situation, this fear was reduced and the fish became more curious.

In Hour 2, the reinforcing properties of each condition reached its maximum. At this point in time the animal adapted to the situation and is most curious. In Hour 3, there is a decrement in responding. This is seen as an indication of increasing satiation to the stimuli until, in Hour 4, there is a still further decrease in total responses as a result of satiation.

From the results it would appear that the sensory reinforcement process operates within the visual modality of at least one species of fish. This finding lends to Kish's notion of the wide range of applicability of sensory reinforcement.

However, the present study does not give much insight into the basic mechanisms underlying the process. Berlyne has stated, "But ludic (i.e. play) behavior must depend just as much as any other behavior on physiological processes. As far as we know, it may have its contribution to make in biological adaptation and, in particular, to the state of bodily equilibrium and well-being that so-called homeostatic processes serve to maintain.





It may well affect prospects of survival (1960, p.6)." This appears to be a reasonable assumption and if it is true, then the underlying "physiological processes" are most probably of a phylogenetically primitive nature. This is not to say that the particular mechanisms operating in the fish are homologous with those operating in higher order vertebrates; rather, it is the functioning of these mechanisms that is similar.

This functional similarity would be congruent with Berlyne's hypothesis that this process probably contributes to biological adaptation. This conclusion can be reached if one considers that in studies concerned with sensory reinforcement, the S emits some behavior which results in an informational input about the environment to the subject. In a natural situation, if an organism were denied this type of information, or did not seek this information, his probability of survival would be determined almost totally by his predators and environment. It could be questioned, why should an organism in a natural situation take time to explore non-significant features of his environment, such as light onset? The answer lies in how the animal can establish whether a given stimulus or change in stimulation is in fact non-significant. One way of determining the significance of a stimulus is through repeated contact with the stimulus (exploration).

The situation in which the organism encounters the stimulus has been shown to be important in determining whether the animal



will explore or not. Barnett has found that wild rats are less likely to examine and more likely to avoid novel objects placed in their cages than are laboratory rats (Barnett, 1963). This could be taken as an indication that if one eventually wishes to establish theories regarding exploratory behavior in a natural setting as opposed to the laboratory situation, it may be necessary to study exploratory behavior in, at least, a more natural context than has been done to date.

#### Future considerations:

It was noted in the procedure section that subjects were chosen if they emitted at least one response in an hour period. This was done to avoid the necessity of shaping the animal to press the target. It could justifiably be argued that the fish which met this criterion represented the more "curious" animals. While this in itself is of no great concern for the present study since each subject served as its own control, it is noteworthy that approximately  $1/3$  of the fish tested failed to meet this criterion. From personal experience it has been found that in rats only a small percentage fail to emit at least one response when placed in a Skinner box. This then could be taken as an indication that over a large sample of fish one would find a less amount of curiosity when compared with a comparable sample of some higher order vertebrate such as the rat.

If one assumes that introduction of an animal into a novel





situation is emotionally arousing, then fish would tend to either become highly active (thus increasing the probability of making a response) or highly inactive (conversely decreasing the probability of making a response) (Haralson & Clement, 1968). This could in part account for the high number of fish that failed to make one response; that a portion of the  $1/3$  of the animals reacted to the test situation by "withdrawing". If this reasoning is correct, then if one could reduce the emotional arousal in fish then there should be a resultant increase in curiosity.





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## Appendix A

### Sub study - Novelty

Besides complexity, another variable which has been of interest in sensory reinforcement has been novelty. As Berlyne has pointed out, novelty is, in itself, a complex notion (Berlyne, 1960).

Out of interest, 4 Ss were randomly selected after they had completed the 5 conditions of the main study. They were placed in the experimental tank and run as before. However, the reinforcement compartment on this trial contained a large artificial clam which opened and closed "its shell", this stimulus being interpreted as novel. However, since the animals were purchased from a commercial source, it would be impossible to classify the type of novelty incorporated in the stimulus.

Figure 8 shows the effect of this novel stimulus on the emitted responses compared with the control ( $C_0$ ), light onset condition ( $E_1$ ), and the fish condition ( $E_2$ ) for each of the animals.

From the data it appears that generally the novel stimulus did not have an enhancing effect over the control condition. The interpretation of this finding could be the same as for the animals who were rejected from the study. This argument is



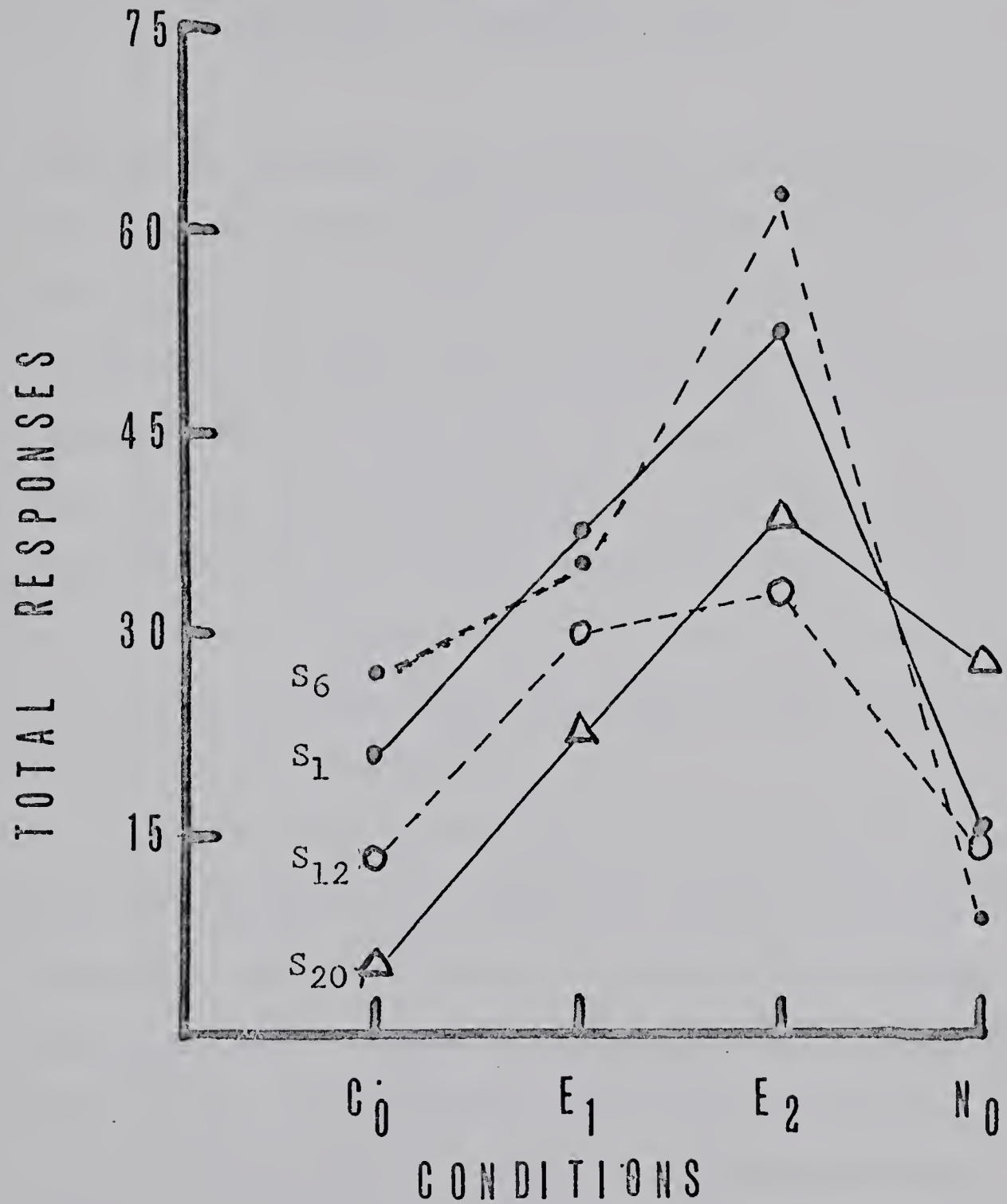


Figure 8 The effect of novelty (N<sub>0</sub>) on total emitted responses compared with responses for 3 conditions (C<sub>0</sub>, E<sub>1</sub>, E<sub>2</sub>) for 4 subjects (S<sub>1</sub>, S<sub>6</sub>, S<sub>12</sub>, S<sub>20</sub>)





developed in Chapter 4 under future considerations.



## Appendix B

### Sub study II - Effect of hunger

Some studies have shown that introduction of a physiological drive state (such as hunger) facilitates exploratory behavior, while other work has demonstrated an inhibitory function.

In the study proper Ss were food satiated prior and during the trials. In order to investigate the subsequent effect of food deprivation on sensory reinforcement, five animals, after they had completed the five conditions in the main study, were deprived of food for 24 hours and then run under the  $E_1$  condition. This food deprived condition was run at least 72 hours after the last condition in the main study.

In each subject, the introduction of food deprivation resulted in a marked decrement in total responding. However, the findings were confounded. The E observed 2 of the fish being run under food deprivation. The Ss appeared to spend the entire test period in search of food. The appetitive behavior was in conflict with target pressing and hence there was a subsequent decrement in emitted responses - due to this incompatibility of responses.



## Appendix C

### Pilot study

A pilot study using 10 fish was run prior to the actual study. The apparatus in this pilot study differed from the one used in the study proper in that there was no aperture wall and pressing the target resulted in the illumination of the otherwise dark reinforcement compartment except for the control condition in which the response produced no change in the reinforcement compartment. The contents of the reinforcement compartment were the same for both the pilot study and the major study.

Because of certain methodological difficulties encountered in the pilot study, the aperture wall was developed. However, the results in both studies are quite similar; the control condition elicited the fewest responses while  $E_4$  elicited the most responses. Again there was a monotonic relationship with conditions ranked  $C_0, E_1, E_2, E_3$ , and  $E_4$ .





## Appendix D

Subject number	Days				
	1	2	3	4	5
1	32	91	43	89	6
2	89	30	85	13	33
3	31	19	98	52	49
4	36	114	116	52	22
5	96	23	39	5	117
6	6	52	10	89	100
7	103	41	62	39	27
8	29	3	41	72	15
9	93	25	8	21	40
10	18	99	82	27	35
11	32	135	36	118	19
12	27	36	103	62	89
13	40	10	38	73	80
14	120	53	86	21	37
15	9	99	53	18	48
16	101	46	15	111	32
17	72	4	21	30	53
18	103	8	18	70	27
19	33	25	6	87	43
20	12	16	26	62	106



Subject number	Appendix				
	DAYS				
	1	2	3	4	5
11	32	91	43	89	6
12	99	30	85	13	33
13	31	19	98	62	49
1	36	114	116	52	22
2	96	23	39	5	117
14	6	52	10	89	110
15	103	41	62	39	27
3	29	3	41	72	15
4	93	25	8	21	40
16	18	99	82	27	35
5	32	135	36	118	19
6	27	36	103	62	89
17	40	10	39	73	80
18	138	53	86	21	37
7	9	99	53	20	48
8	101	46	15	111	32
9	72	4	21	30	53
19	103	8	18	70	27
20	33	25	6	87	43
10	12	16	26	62	111





Appendix E

	E <sub>1</sub>				E <sub>2</sub>				E <sub>3</sub>				E <sub>4</sub>				
	H <sub>1</sub>	H <sub>2</sub>	H <sub>3</sub>	H <sub>4</sub>	H <sub>1</sub>	H <sub>2</sub>	H <sub>3</sub>	H <sub>4</sub>	H <sub>1</sub>	H <sub>2</sub>	H <sub>3</sub>	H <sub>4</sub>	H <sub>1</sub>	H <sub>2</sub>	H <sub>3</sub>	H <sub>4</sub>	
S <sub>1</sub>	5	4	8	5	9	17	7	3	4	13	19	16	20	62	18	16	14
S <sub>2</sub>	0	3	1	1	5	8	9	1	4	18	11	6	10	43	30	13	11
S <sub>3</sub>	0	1	2	0	1	9	3	2	1	5	14	9	5	19	12	5	12
S <sub>4</sub>	1	3	4	0	3	9	6	3	6	10	7	2	9	11	15	5	20
S <sub>5</sub>	5	11	1	2	3	18	7	8	8	17	4	3	9	37	35	37	15
S <sub>6</sub>	3	12	7	5	4	15	8	9	14	31	10	7	10	37	31	11	6
S <sub>7</sub>	3	5	0	1	2	7	8	3	6	23	15	9	3	18	12	15	4
S <sub>8</sub>	3	4	2	6	11	6	10	5	12	15	11	8	13	35	40	13	8
S <sub>9</sub>	0	1	3	0	5	14	7	4	3	7	9	2	9	20	18	6	11
S <sub>10</sub>	6	9	1	0	2	7	2	1	3	5	10	8	7	6	33	16	14
S <sub>11</sub>	1	0	4	1	5	12	13	2	2	17	19	5	10	33	21	27	13
S <sub>12</sub>	6	3	4	0	0	12	17	1	7	9	11	6	10	28	40	21	15
S <sub>13</sub>	2	3	7	7	6	16	5	4	9	27	14	12	7	10	21	11	15
S <sub>14</sub>	0	2	3	1	2	4	0	4	8	16	18	10	18	19	31	21	23
S <sub>15</sub>	5	12	6	4	8	29	3	1	3	14	16	6	10	19	25	8	6
S <sub>16</sub>	9	5	4	0	5	9	13	8	3	8	11	5	4	56	18	4	21
S <sub>17</sub>	0	3	6	1	1	16	17	6	7	15	11	6	15	31	21	13	11
S <sub>18</sub>	4	7	6	4	11	19	4	3	8	31	8	6	9	42	16	19	20
S <sub>19</sub>	0	4	3	1	3	8	4	3	6	12	5	4	10	42	12	6	18
S <sub>20</sub>	0	1	4	1	8	11	5	1	16	11	6	0	10	15	12	6	7
AM																	
PM																	

AM

PM







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